PHYSICAL AND CHEMICAL PROPERTIES OF FLANNELS CONTAINING DIFFERENT PROPORTIONS OF NEW AND REPROCESSED WOOL [1]

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INTRODUCTION

Recent efforts to secure "truth in fabrics" legislation, requiring manufacturers to label textiles containing wool with the percentages of new wool present,[3] have led to interest in the quality of fabrics containing new and reprocessed wool in various proportions. South Dakota as a wool-producing State has an interest in variations or differences in the physical and chemical properties of fabrics containing mixtures of new and reprocessed wool. Accordingly in 1938 a study of certain physical and chemical properties of flannel fabrics manufactured from mixtures of new wool and shoddy was initiated. While performance tests of the fabrics have not as yet been conducted, it has been possible to determine the effects of dry cleaning and pressing upon the fabric properties.

Relatively few reports have appeared of investigational work on wool fabrics of known composition. The spinning and weaving qualities of wool from British pedigreed sheep were investigated at the University of Leeds (*7, 8, 9*)[4] and the fiber, yarn, and fabric characteristics determined. Another study of the same type on wool from British breeds of sheep was reported by Barker (*3*) to the New Zealand Government. The Bureau of Animal Industry of the United States Department of Agriculture, in cooperation with the Bureau of Home Economics, has recently published the results of a study of the serviceability of blankets made from four blends of wool (*5*). Wools selected from purebred flocks of Rambouillet and Corriedale sheep and reworked fiber were used in the manufacture of the blankets. The fabrics were given actual service tests, and the rates of chemical and physical deterioration were determined. These Bureaus have in progress further work with blankets involving the use of various grades of reprocessed wool and mohair in comparison with new wool[5] and of suitings made from blends of new wool with reprocessed wool and spun rayon.[6]

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[3] The Wool Products Labeling Act, passed by the 76th Cong., 3d sess., was approved October 14, 1940, and became effective July 14, 1941.

[4] Italic numbers in parentheses refer to Literature Cited, p. 597.

[5] Hays, Margaret B., Rogers, R. E., and Hardy, J. I. NOTES ON GRADUATE STUDIES AND RESEARCH IN HOME ECONOMICS AND HOME ECONOMICS EDUCATION, 1938-39. U. S. Dept. Agr., Off. Expt. Stat., 219 pp. [Mimeographed.] (See p. 121.)

[6] See p. 119 of the reference cited in footnote 4.

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MATERIALS

Rambouillet sheep, raised at South Dakota State College, furnished the new wool used in the present experiment. Ten fleeces weighing approximately 10 pounds each were shipped to the Lowell Textile Institute for fabrication. Reprocessed wool of a high quality from pastel sweater clippings was purchased on the market by members of the institute staff and blended with the new wool. The fiber used for the first fabric (No. 100) was made of 100 percent new wool; for the second (No. 75), approximately 75 percent new wool and 25 percent reprocessed wool; for the third (No. 50), approximately 50 percent new wool and 50 percent reprocessed wool; for the fourth (No. 25), approximately 25 percent new wool and 75 percent reprocessed wool. The exact weights of the fibers are recorded in table 1, which shows that considerable machine waste resulted in the course of the manufacturing. Thus, while the fiber blends indicated above were used as the raw materials for each of the fabrics, these percentages may not have been maintained in manufacture. Further evidences of shifts in these percentages will be indicated in the discussion below.

Emulsion consisting of 75 percent water and 25 percent oil (fat and mineral oil) was applied to the stock in picking. All of the lots were spun to 3½ run Z twist and an identical lay-out was used consisting of No. 9 reed, 4 yarns per dent, 1,560 warps, 43½ inches in reed, and 36 fillings, resulting in a 2 × 2 even-twill fabric. After weaving, each fabric was given a simple finishing process consisting of washing and pressing. The finished yardage and weight as reported by Lowell Textile Institute are shown in table 1.

TABLE 1.—*Weights of new and reprocessed wool fiber used in manufacturing the four experimental fabrics, and length, width, and finished weight of the four fabrics*

Fabric No.	Fiber weights used[1]		Finished fabric—			
	New wool	Reprocessed wool	Length	Width	Weight	
	Pounds	*Pounds*	*Yards*	*Inches*	*Pounds*	*Ounces*
100	14.4	0.0	20.6	35.5	9	10
75	10.8	3.5	20.4	36.4	9	6
50	7.2	7.0	20.9	36.0	9	4
25	4.0	------------	18.0	36.5	7	8

[1] Total carding and spinning waste for the 4 fabrics was 16 pounds.

METHODS

PHYSICAL-PROPERTY DETERMINATIONS

Each of the four fabrics manufactured was tested physically and chemically as it was received from the manufacturer and after it had been commercially dry-cleaned and pressed 15, 30, and 45 times. The process used in dry cleaning was described as consisting of running in dry-cleaning solvent (Stoddard solvent) in a regular cylindrical dry-cleaning washer for 10 minutes with paste soap and rinsing for 20 minutes on a filter so constructed as to remove the heavy "soil" from the solvent. The solvent was passed continuously from the the washer through the filter and returned again to the washer. After each cleaning the fabrics were pressed on a regular steam press.

Throughout this investigation all testing requiring the maintenance of moisture equilibrium in the fabrics was conducted in a conditioning room maintained at a standard atmosphere of 65 percent relative humidity ±2 percent at 70° F. ±2, as specified by the American Society for Testing Materials (*2, p. 184*). All samples were conditioned for a minimum of 6 hours before testing. Samples used in determining weight per square yard and yarn number were dried to constant weight at 105° C. Yarn-count and twist determinations were conducted under prevailing atmospheric conditions, as were all fiber studies.

The means and standard deviations of measurements were calculated in all instances possible, and the analysis of variance for significance of difference between means was applied in some cases.

A 1-pound sample of scoured new-wool fiber was taken from various parts of the lot for use in measurements of fiber diameter, contour, length, and crimp, and a similar sample was taken from the reprocessed wool in the oil. Portions of the fiber samples were hand-carded and carefully blended. By means of intestinal forceps, recommended by Townsend (*11*) for sampling fiber for length determinations, repeated draws were made and blended until samples of the correct size for each type of fiber measurement were secured.

A modification of the cross-section method recommended by the American Society for Testing Materials (*2, p. 174*) was used to determine the diameter and contour of the new and reprocessed wool. The device described by Hardy (*1*) was used in preparing the cross-sectional microscopic slides. The cross-section mounts were placed on a microscope stage set at right angles to the base and, by the use of strong artificial light, their images were projected onto a ground-glass plate placed at such a distance from the microscope that each fiber section was magnified approximately 500 times. One thousand fiber sections were measured to an accuracy of one micron, as recommended by the American Society for Testing Materials (*2*), at (1) their greatest diameters and (2) the diameters at right angles to their greatest diameters.

The samples for determination of fiber length were prepared according to the method described by Townsend (*11*). Three groups of 150 fibers each were measured to the nearest 0.25 inch by extending the fiber sufficiently to remove the crimp but not to stretch it.

The number of crimps in each fiber measured for length was counted over the entire length, and the average number of crimps per inch was calculated.

Yarn number in the present study was recorded as the number of thousands of yards per pound (typp system). Prior to the determination three 10-yard lengths were dried to constant weight. In the preparation of the samples an attempt was made to measure lengths of yarn from which the crimp had been removed without stretching the yarn. The resulting values were calculated in typp to 13 percent regain—the standard regain for woolen yarn (*2*)—and the results used in the adjustment of tension in determining yarn twist.

The average number of twists per inch was determined using the new-type Suter precision twist tester with spinning twist attachment. The gage length was 10 inches and 50 yarns per sample were measured.

A Scott single-strand tester with autographic recorder was used in the determination of yarn stength. The clamps were set 10 inches apart and moved at a speed of 12 inches per minute. Tensile strength and elongation of yarns removed from the fabric at scattered points were measured in each instance.

Wherever the nature of the test made such measurements possible, samples of both warp and filling sections of fabric were prepared. With the exception of the method for abrasion, all methods were standard procedures of the American Society for Testing Materials (*2*).

Two-inch squares taken at five scattered positions on each fabric were composited for the determination of fabric weight. All of the results were calculated to 13-percent regain and expressed in ounces per square yard.

Measurements of thickness were made on each of 10 grab tensile-strength samples by means of the Schiefer compressometer with a ⅜-inch foot at a pressure of 3.4 pounds per square inch. The results were recorded in the number of 0.001 inch of thickness.

A Lowinson counter was used for the determination of the number of yarns per inch. The 10 samples of fabric prepared for the determination of strength by the strip method were measured for a distance of 1 inch.

A 10-inch square was marked on each fabric before it was sent to a commercial dry cleaner and was measured on its return. Thus shrinkage is reported in percentage shrinkage after 15, 30, and 45 dry cleanings and pressings.

J-type Scott testers with recording serigraphs were used throughout for the determination of the tensile strength and elongation of the experimental samples. A 150- to 300-pound-capacity machine was used for the grab samples and a 55- to 110-pound-capacity machine for the strip samples. Ten strips of fabric to form the sample were cut 1½ inches wide by 6 inches long and were raveled to 1 inch. Two-inch fabric jaws set 3 inches apart were employed in the strip tests. Ten grab tensile-strength samples per fabric were cut 4 inches wide and 6 inches long. One-inch front and 3-inch back jaws were used for the grab determinations. On both machines the jaws traveled at the rate of 12 inches per minute. Tensile-strength values were recorded in pounds and elongation in inches.

The ball-burst attachment for the Scott tester was used for the determination of bursting strength. Metal balls 1 inch in diameter and 1¾-inch rings were employed. Ten determinations were made on each fabric, and the results were recorded in terms of force in pounds required to thrust the ball through the fabric. Stretch was recorded by means of the serigraph.

The test specimens used in the determination of tearing strength by the tongue method were cut 3 by 8 inches in size. Three-inch longitudinal cuts were made lengthwise of the specimens from the center of one of the edges. The 55-pound-capacity Scott tester was employed, and the autographic recording device was used to record the average load necessary to break. A planimeter was used in calculating the average tearing strength of the fabrics.

Ten samples of each fabric 1⅞ by 10 inches in size were abraded on the Wyzenbeck precision wear testmeter, with a monel-metal screen used as the abrasive surface. The fabrics were given 1,000 double rubs at 4 pounds pressure at an initial tension of 3 pounds. After abrasion, the tensile strength (strip) of the samples was determined by the methods already outlined.

CHEMICAL-PROPERTY DETERMINATIONS

Samples of fiber and fabrics in the various conditions studied were analyzed in duplicate for their moisture, ash, sulfur, and nitrogen content. Both fiber and yarn were cut into smal pieces to facilitate adequate sampling. Moisture was determined by drying to constant weight in a drying oven at 40° C. One-gram samples were ashed to constant weight and total ash recorded in percentage. The Parr Bomb was used in determining the total sulfur of 0.5-gm. samples, and the percentage of sulfur was calculated. The percentage of total nitrogen was determined upon 1-gm. samples by the Kjeldahl method, with copper sulfate used as the catalyst.

PRESENTATION AND DISCUSSION OF EXPERIMENTAL RESULTS

In the discussion of the results of this investigation, consideration is given first to the properties of the new and reworked fibers. Chemical determinations upon the fabrics after progressively greater numbers of dry cleanings were made, and the results of the application of the analysis of variance to the physical measurements of fabric strength are then discussed.

TABLE 2.—*Mean and standard-deviation values for length, crimp, diameter, and contour measurements of new and reprocessed wool*

Wool fiber	Length		Crimp per inch		Diameter		Contour ratio	
	Mean [1]	Standard deviation	Mean [1]	Standard deviation	Mean [2]	Standard deviation	Mean [2]	Standard deviation
	Inch	*Inch*	*Number*	*Number*	*Microns*	*Microns*		
New	2.49	0.96	13.34	3.03	21.16	5.03	1.25	0.143
Reprocessed	1.78	.88	11.95	5.00	25.72	7.22	1.25	.193

[1] 450 determinations.
[2] 1,000 determinations.

COMPARISON OF NEW AND REPROCESSED WOOL FIBERS

The physical characteristics of the new and reprocessed wool fibers are shown in table 2. From these data it may be seen that the average length of the new fiber was 40 percent greater than that of the reprocessed wool and the average number of crimps per inch was over 10 percent greater in the new wool. According to the blood system of grading wool, the virgin wool would be classed as fine and the reprocessed wool as half blood. No difference in average contour ratio was found in the wool. In all the physical measurements made, relative variability was greater in the reprocessed than in the new wool.

TABLE 3.—*Ash, nitrogen, and sulfur content of the new and reprocessed wool fiber, on a moisture-free basis*

Wool fiber	Ash	Nitrogen	Sulfur
	Percent	*Percent*	*Percent*
New	0.98	13.50	3.52
Reprocessed	.41	12.63	3.71

The ash, nitrogen, and sulfur content was determined for the new- and reprocessed-wool fibers with the results given in table 3.

The ash content of the new wool was more than twice that of the reprocessed wool, and the nitrogen content was approximately 1 percent greater. The sulfur content was 0.19 percent lower in the new wool.

COMPARISON OF FABRICS MANUFACTURED FROM NEW AND REPROCESSED WOOL

PHYSICAL AND CHEMICAL PROPERTIES OF FABRICS AS RECEIVED FROM THE MANUFACTURER

In the discussion of the manufacture of the fabrics it was noted that identical methods were used throughout in the preparation of yarns and in the weaving and finishing processes. When the finished materials were examined, it was evident that the fabrics produced from the various blends did not have the same properties. The data in table 4 shows that the average weight per square yard decreased as the percentage of reprocessed wool increased. Thickness and twist were approximately the same throughout the series, and the number of yarns per inch decreased slightly with increasing percentages of reprocessed wool.

In discussing the relative merits of the four fabrics, the fact that inherent differences were present in them must be kept in mind. Since correction factors accounting for the complexity of factors are not available, the data reported are those of the actual results obtained, the constant factors being identical manufacture and dry-cleaning processes rather than identity in finished fabric.

TABLE 4.—*Mean values for characteristics of the 4 fabrics containing different percentages of new and reprocessed wool fiber*

Fabric No.[1]	Weight per square yard [2]	Thickness	Yarns per inch		Shrinkage [3]		Twists per inch	
			Warp	Filling	Warp	Filling	Warp	Filling
	Ounces	*0.001 inch*	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*
100-0	7.92	32.2	44.3	36.2			11.7	12.4
100-15	8.75	35.4	45.2	38.5	5.0	1.2	12.5	12.8
100-30	8.94	36.5	45.9	39.3	6.2	1.2	12.8	12.9
100-45	8.48	36.0	45.3	39.3	6.2	1.2	12.9	12.8
75-0	7.71	32.8	43.3	35.9			12.2	12.4
75-15	8.45	36.0	44.2	37.9	3.8	1.2	12.3	12.4
75-30	8.69	36.4	44.8	38.0	6.2	1.2	12.7	12.4
75-45	8.90	36.2	44.7	38.3	6.2	1.2	12.6	12.5
50-0	7.36	33.0	43.0	35.4			12.4	12.5
50-15	7.77	35.2	43.9	37.2	3.8	1.2	12.6	12.6
50-30	8.29	35.4	44.5	38.5	6.2	1.2	12.5	12.6
50-45	7.76	35.2	43.9	38.2	6.2	1.2	12.5	12.6
25-0	6.71	31.6	42.9	35.3			12.1	12.4
25-15	7.01	33.8	43.5	38.2	3.8	1.2	12.0	12.2
25-30	7.32	33.2	43.7	37.8	5.0	1.2	12.2	12.4
25-45	7.28	33.6	43.4	38.2	5.0	1.2	12.3	12.7

[1] The numerals following the dash indicate the number of dry cleanings and pressings undergone by the fabrics.
[2] 13 percent regain.
[3] Caused by dry cleaning and pressing

Since fabric weight decreased progressively with increasing percentages of reprocessed wool, it must be concluded that there was more carding and spinning waste as the percentage of reprocessed wool was increased. In this same connection, a comparison of the average diameter of the fiber present in the finished fabrics is of significance. The results of this study are shown in table 5. From these data it is apparent that in the case of the 100-percent virgin fabric the manufacturing processes did not affect either the average diameter or the distribution as measured by the standard deviation. It would be anticipated that the average diameter of the wool present in the fabrics containing reprocessed wool would increase, approaching that of the reprocessed fiber as the percentage of reprocessed fiber became higher. However, as is shown in table 5, the diameter increased but slightly. Thus in the manufacturing processes the coarser reprocessed fiber must have been eliminated to a certain extent. Since the contour ratios of the new and the reprocessed fiber were the same, no change in contour ratio would be anticipated throughout the series of fabrics; and, in fact, the actual differences found are not to be considered significant from a practical standpoint.

TABLE 5.—*Diameter and contour ratios of the fibers in the new and reprocessed wool and in the manufactured fabrics*

Sample [1]	Diameter		Contour ratio	
	Mean	Standard deviation	Mean	Standard deviation
	Microns	*Microns*		
New fiber	21.16	5.03	1.25	0.143
Reprocessed fiber	25.72	7.22	1.25	.193
Fabric No.—				
100	21.30	5.16	1.24	.140
75	21.71	5.52	1.24	.142
50	21.77	5.73	1.25	.158
25	22.04	6.56	1.23	.139

[1] Size of sample, 1,000.

EFFECTS ON FABRICS OF DRY CLEANING AND PRESSING

In table 6 are shown the results of the ash, nitrogen, and sulfur analyses of the four fabrics as received from the manufacturer and after various numbers of dry cleanings and pressings. It will be noted that, with few exceptions, the tendency was for the percentage of ash to increase with dry cleaning. In all four fabrics there was a marked increase in nitrogen between the fifteenth and thirtieth dry cleanings, an increase which could not be accounted for on the basis of any of the other physical or chemical experimental results. It has

TABLE 6.—*Ash, nitrogen, and sulfur content on a moisture-free basis of the four fabrics containing different percentages of new and reprocessed wool fiber*

Fabric No.	Ash	Nitrogen	Sulfur	Fabric No.	Ash	Nitrogen	Sulfur
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
100-0	0.48	13.55	3.34	50-0	0.64	13.50	3.47
100-15	.97	13.15	3.54	50-15	1.02	13.38	3.39
100-30	.94	15.83	3.37	50-30	.91	15.99	3.36
100-45	1.08	15.78	3.74	50-45	1.14	15.67	3.43
75-0	.66	13.58	3.63	25-0	.61	13.42	3.44
75-15	.83	13.07	3.59	25-15	.98	13.15	3.33
75-30	.91	15.66	3.58	25-30	.84	15.55	3.41
75-45	1.00	15.45	3.34	25-45	1.36	15.57	3.27

been suggested that accumulation of the paste soap might have been responsible, but no analysis of the soap is available. Sulfur determinations indicate that no fabric blend or treatment affected the results to a greater or less extent than any other throughout the series. In some instances a fabric sample had a higher sulfur content as a result of one stage of treatment, whereas in other fabrics this treatment apparently caused a lowering of the sulfur content.

In the discussion of the effects of abrasion and dry cleaning and pressing, statistical methods have been applied in the comparisons of the four fabrics in the various stages of treatment. All of the data reported in tables 7 to 10 are involved in the calculations.

TABLE 7.—*Mean and standard-deviation values for the yarn-strength and elongation measurements of the experimental fabrics as affected by dry cleaning and pressing*

Fabric No.[1]	Yarn strength				Yarn elongation			
	Warp		Filling		Warp		Filling	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Grams	*Grams*	*Grams*	*Grams*	*Centimeters*	*Centimeters*	*Centimeters*	*Centimeters*
100-0	311.2	52.02	287.6	55.90	5.09	0.929	5.06	0.890
100-15	337.9	49.52	285.7	49.49	4.88	.842	4.61	.874
100-30	319.5	52.45	327.9	47.61	4.67	1.023	4.86	.960
100-45	317.2	42.63	300.2	42.12	4.32	.857	4.51	.830
75-0	268.3	35.55	282.7	27.26	4.38	.883	4.76	.782
75-15	288.6	46.33	287.5	32.97	4.16	.876	4.39	.821
75-30	262.8	44.43	267.3	43.42	3.91	.869	4.01	.919
75-45	261.2	34.08	248.9	30.05	4.05	.634	4.18	.693
50-0	224.0	36.10	196.4	24.54	3.92	.781	3.83	.879
50-15	222.6	29.66	193.0	20.15	3.52	.665	3.68	.659
50-30	221.6	36.18	196.8	32.51	3.47	.790	3.69	.712
50-45	213.7	32.67	196.4	28.57	3.53	.669	3.25	.605
25-0	171.5	31.68	181.0	35.34	2.89	.693	3.27	.723
25-15	169.5	32.78	164.1	29.21	2.66	.661	2.91	.676
25-30	159.8	26.99	148.3	28.41	2.64	.625	2.65	.609
25-45	170.3	30.99	149.7	24.59	2.78	.676	2.79	.693

[1] Size of sample, 50.

TABLE 8.—*Mean and standard-deviation values for strip tensile-strength and elongation measurements of the experimental fabrics before and after abrasion*

BEFORE ABRASION

Fabric No.[1]	Strip breaking strength				Strip elongation			
	Warp		Filling		Warp		Filling	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Inches*	*Inches*
100-0	36.4	1.18	27.2	0.86	0.84	0.149	1.07	0.066
100-15	37.0	1.01	30.6	1.27	1.05	.202	1.08	.094
100-30	36.8	.68	30.9	1.39	.98	.081	1.10	.081
100-45	35.7	.95	28.4	1.31	.97	.066	1.06	.094
75-0	30.2	.63	24.1	.92	.71	.058	.99	.075
75-15	31.2	1.14	26.8	1.11	.85	.058	1.11	.128
75-30	30.4	1.17	25.7	1.93	.80	.066	.93	.316
75-45	31.2	1.18	23.6	1.02	.85	.100	.93	.316
50-0	25.7	.89	19.0	.67	.58	.094	.83	.081
50-15	27.0	.67	19.8	.53	.65	.058	.86	.047
50-30	26.1	1.22	21.4	.64	.70	.066	.88	.047
50-45	25.4	.88	20.0	.60	.66	.066	.81	.034
25-0	21.2	.47	15.1	.78	.44	.047	.63	.047
25-15	22.2	.75	17.5	1.29	.60	.000	.72	.081
25-30	21.6	1.14	16.0	.83	.62	.047	.72	.047
25-45	21.0	.68	16.0	.83	.62	.066	.73	.047

[1] Size of sample ,10.

TABLE 8.—*Mean and standard-deviation values for strip tensile-strength and elongation measurements of the experimental fabrics before and after abrasion*—Con.

AFTER ABRASION

Fabric No.[1]	Strip breaking strength				Strip elongation			
	Warp		Filling		Warp		Filling	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Inches*	*Inches*
100-0	35.6	0.63	28.7	1.36	0.79	0.088	1.01	0.111
100-15	37.0	1.01	31.2	1.51	.87	.066	.99	.058
100-30	37.0	.68	30.4	1.11	.98	.081	1.04	.066
100-45	35.4	.58	30.4	1.85	.91	.100	1.02	.081
75-0	30.2	1.09	25.3	.89	.65	.089	.84	.081
75-15	31.0	.55	26.6	1.46	.73	.066	.91	.075
75-30	30.6	.83	26.4	.98	.80	.081	.95	.058
75-45	31.1	1.93	26.8	1.51	.78	.066	.89	.075
50-0	26.8	.43	20.2	.79	.53	.047	.74	.047
50-15	26.8	.72	21.0	.91	.64	.047	.75	.075
50-30	26.5	.74	21.0	.53	.66	.047	.73	.047
50-45	25.8	1.00	21.8	.97	.69	.058	.72	.045
25-0	21.8	.75	16.0	1.05	.45	.058	.61	.058
25-15	21.6	.52	16.4	.81	.52	.047	.63	.047
25-30	21.3	.42	16.0	1.03	.54	.047	.60	.047
25-45	20.8	.89	16.6	.70	.55	.058	.61	.058

[1] Size of sample, 10.

TABLE 9.—*Mean and standard-deviation values for grab breaking-strength and elongation measurements of the experimental fabrics as affected by dry cleaning and pressing*

Fabric No.[1]	Grab breaking strength				Grab elongation			
	Warp		Filling		Warp		Filling	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Inches*	*Inches*
100-0	52.0	1.25	43.8	2.30	0.79	0.058	1.03	0.066
100-15	52.1	1.81	45.8	2.19	.82	.047	1.06	.066
100-30	53.7	2.10	47.8	2.83	.90	.081	1.16	.133
100-45	49.6	1.63	44.0	2.81	.90	.081	1.05	.100
75-0	42.5	2.51	35.4	2.49	.77	.094	.99	.075
75-15	42.9	1.37	40.4	1.45	.80	.081	.97	.081
75-30	42.5	1.58	37.0	1.82	.83	.066	.92	.047
75-45	42.0	1.05	37.0	1.95	.76	.066	.93	.066
50-0	35.6	2.77	29.0	2.03	.66	.081	.95	.145
50-15	35.9	1.85	29.1	1.43	.65	.058	.85	.088
50-30	35.5	1.81	29.5	1.65	.70	.047	.83	.066
50-45	34.5	1.03	28.8	1.77	.68	.094	.80	.094
25-0	27.0	1.04	22.6	1.10	.45	.058	.73	.066
25-15	27.8	.88	24.2	1.12	.55	.058	.73	.066
25-30	28.1	1.10	23.0	1.09	.54	.047	.69	.075
25-45	26.6	1.22	23.1	.97	.53	.047	.67	.047

[1] Size of sample, 10.

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TABLE 10.—*Mean and standard-deviation values for the bursting-strength, bursting-elongation, and tearing-strength measurements of the experimental fabrics as affected by dry cleaning and pressing*

Fabric No. [1]	Bursting strength		Bursting elongation		Tearing strength			
					Warp		Filling	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Pounds	*Pounds*	*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
100–0	81.4	2.92	0.50	0.000	5.85	0.242	6.10	0.460
100–15	88.6	4.67	.52	.079	4.80	.350	5.05	.370
100–30	88.6	2.57	.50	.000	5.15	.338	4.85	.338
100–45	87.7	2.89	.50	.000	4.90	.316	4.50	.236
75–0	77.6	3.14	.52	.079	4.95	.160	4.80	.350
75–15	78.8	2.81	.48	.079	4.35	.242	4.20	.258
75–30	76.0	2.83	.42	.120	4.35	.242	4.40	.316
75–45	78.9	2.45	.48	.079	4.30	.258	4.35	.242
50–0	65.1	2.21	.48	.079	4.50	.236	4.40	.211
50–15	65.6	1.61	.40	.128	4.05	.160	3.75	.264
50–30	66.9	3.10	.45	.105	4.05	.100	3.65	.242
50–45	67.0	2.71	.48	.079	4.05	.285	3.85	.242
25–0	56.2	3.84	.48	.079	3.95	.160	4.20	.258
25–15	60.6	1.44	.48	.079	3.85	.242	3.65	.242
25–30	60.3	2.44	.50	.000	3.90	.316	3.80	.258
25–45	59.0	2.27	.40	.128	3.95	.285	3.75	.264

[1] Size of sample, 10.

After subjecting samples of each of the experimental fabrics to mechanical abrasion, strip tensile-strength samples were cut and tensile strength following abrasion for 1,000 double rubs was determined. The results of these measurements are recorded in table 8. "Student's" *t* test for significance of difference of means has been applied in comparing the strength and elongation values for the fabrics before and after the abrasion treatment (table 8). Nonsignificant differences were found in both warp and filling determinations of strength. In elongation measurements the means of both warp and filling determinations were found to differ significantly. Thus, with five exceptions, elongation was found to decrease after abrasion without causing a decrease in strength.

Since homogeneity of errors is assumed in the calculations of the analysis of variance, the χ^2 test was used to determine whether the variability of the strength and elongation measurements for the fabrics subjected to the various numbers of dry cleanings and pressings were homogeneous (Snedecor, *10*). The results indicated in table 11 show that this was true in all instances.

TABLE 11.—*Analysis of errors of strength and elongation measurements of the fabrics by means of the χ^2 test for homogeneity*

Measurement	χ^2 for—			
	Strength		Elongation	
	Warp	Filling	Warp	Filling
Yarn	3.99	4.45	2.86	2.62
Strip:				
Before abrasion	2.74	3.67	3.44	2.04
After abrasion	2.63	3.70	3.34	2.61
Grab	3.82	4.60	2.53	1.75
Bursting [1]	2.21	----------	.50	----------
Tear	1.08	1.54	----------	----------

[1] Fabric direction not involved in bursting-strength determination.

The analysis of variance suggested by Fisher (*4*) was applied to the measurements of yarn and fabric strength and elongation in order to test for significance of differences between fabrics and treatments (dry cleaning and pressing). There were 4 fabrics receiving 4 treatments, 10 measurements being made for fabrics and 50 for yarns. The degrees of freedom are shown in table 12.

TABLE 12.—*Degrees of freedom involved in the analysis of variance of the measurements of yarn and fabric strength and elongation*

Variation due to—	Degrees of freedom	
	Fabric studies	Yarn studies
Blend	3	3
Treatment	3	3
Blend × treatment	9	9
Residual (error)	144	784
Total	159	799

In the analysis of the data based upon these tests of significance (table 13), consideration is given first to the cases in which the residual component is used as error and finally to those in which blend × treatment is used as error. If the residual is used as error, the interpretation applies to the specific fabrics and treatments involved in this study. However, it is of interest to expand the interpretation to

TABLE 13.—*F values by means of the analysis of variance for yarn- and fabric-strength, and for yarn- and fabric-elongation determinations, using residual and interaction as errors*

STRENGTH DETERMINATIONS

Measurement and source of variation	Degrees of freedom	*F* values			
		Warp		Filling	
		Residual as error	Interaction as error	Residual as error	Interaction as error
Yarn strength:					
Blend	3	[1] 565.84	[1] 310.82	[1] 655.32	[1] 64.55
Treatment	3	[1] 5.66	3.11	[1] 5.25	.52
Blend × treatment	9	1.82		[1] 10.15	
Strip strength before abrasion:					
Blend	3	[1] 1,857.98	[1] 1,074.97	[1] 1,166.64	[1] 184.96
Treatment	3	[1] 10.90	[2] 6.30	[1] 45.25	[1] 7.17
Blend × treatment	9	1.73		[1] 6.31	
Strip strength after abrasion:					
Blend	3	[1] 2,076.27	[1] 589.05	[1] 1,134.07	[1] 773.76
Treatment	3	[1] 6.15	1.74	[1] 11.44	[1] 7.80
Blend × treatment	9	[1] 3.52		1.46	
Grab strength:					
Blend	3	[1] 1,573.91	[1] 869.96	[1] 1,069.77	[1] 476.14
Treatment	3	[1] 8.84	[2] 4.89	[1] 12.32	[2] 5.48
Blend × treatment	9	1.81		[2] 2.25	
Tearing strength:					
Blend	3	[1] 181.91	[1] 32.09	[1] 165.05	[1] 23.03
Treatment	3	[1] 39.66	[1] 7.00	[1] 62.37	[1] 8.70
Blend × treatment	9	[1] 5.67		[1] 7.17	
Bursting strength: [3]					
Blend	3	[1] 681.38	[1] 201.47		
Treatment	3	[1] 11.25	3.29		
Blend × treatment	9	[1] 3.38			

See footnotes at end of table.

TABLE 13.—*F values by means of the analysis of variance for yarn- and fabric-strength, and for yarn- and fabric-elongation determinations, using residual and interaction as errors*—Continued

ELONGATION DETERMINATIONS

Measurement and source of variation	Degrees of freedom	F values			
		Warp		Filling	
		Residual as error	Interaction as error	Residual as error	Interaction as error
Yarn elongation:					
Blend	3	[1] 230.94	[1] 137.67	[1] 218.44	[1] 102.50
Treatment	3	[1] 11.45	[2] 6.83	[1] 18.15	[1] 8.52
Blend × treatment	9	1.68		[2] 2.13	
Strip elongation before abrasion:					
Blend	3	[1] 155.25	[1] 56.54	[1] 204.26	[1] 54.50
Treatment	3	[1] 20.36	[1] 7.44	[1] 8.35	2.23
Blend × treatment	9	[1] 2.74		[1] 3.75	
Strip elongation after abrasion:					
Blend	3	[1] 223.95	[1] 229.54	[1] 286.07	[1] 160.64
Treatment	3	[2] 3.55	3.64	1.53	.86
Blend × treatment	9	.98		1.78	
Grab elongation:					
Blend	3	[1] 186.48	[1] 93.14	[1] 137.27	[1] 42.62
Treatment	3	[1] 8.43	[2] 4.21	[2] 3.80	1.18
Blend × treatment	9	[2] 2.00		[1] 3.22	
Bursting elongation: [3]					
Blend	3	[2] 3.41	1.67		
Treatment	3	1.13	.55		
Blend × treatment	9	[2] 2.03			

[1] Exceeds 1-percent point.
[2] Exceeds 5-percent point.
[3] Fabric direction not involved in bursting-strength determinations.

indicate the general effects of mixing new and reprocessed wool and the effect of dry-cleaning and pressing processes. As has been suggested by Immer (*6*), the interaction is the proper error in this case.

When the residual is used as error, the blends are found to differ significantly in strength and elongation in all of the yarn and fabric measurements (table 13). Highly significant differences would be anticipated by examination of tables 7 through 10, reporting the actual strength and elongation results. It may further be noted from these data that, in general, strength decreased regularly as the percentage of reprocessed wool became greater.

With the exception of bursting elongation, in which significant differences were found between the blends, highly significant differences between blends were present. Thus, as is shown in table 7 through 10, elongation decreased with increasing percentages of reprocessed fiber.

If the residual component is used as error in testing for the effects of dry cleaning and pressing (treatment), highly significant differences are found in all instances of strength determinations and in two instances of elongation determinations. This may be seen by examination of the data in table 13.

If consideration is given to the totals for blends receiving the same treatment, the reason for the existence of significant differences between treatments becomes evident. The strength measurements are found to be greater at 15 dry cleanings, with progressively decreasing values after 30 and 45 dry cleanings in five cases; values decrease throughout in the case of the tearing-strength measurements in the filling direction; increase at 15 dry cleanings, decrease at 30, and again increase at 45, following abrasion, in the filling direction; increase progressively through 30 dry cleanings and decrease at 45 dry cleanings in grab and abrasion measurements of the warp; while two measurements, tearing strength of the warp and filling, show marked decreases after 15 dry cleanings, remain approximately the same through 30 dry cleanings, and then decrease after 45 dry cleanings.

The effects of dry cleaning and pressing on elongation are not necessarily of the same order as those on the strength measurements. The totals are found to increase after 15 dry cleanings and then gradually to decrease in the filling direction of the grab determinations; to increase at 15 dry cleanings and remain approximately the same throughout in the warp direction of the strip determinations; to increase through 30 dry cleanings and decrease at 45 dry cleanings in the warp and filling abrasion and warp grab measurements; and to decrease progressively in the remaining four instances.

The third question of interest is whether the effect of treatment upon the four blends was similar. The test of significance is made by dividing the mean square for interaction by the error mean square. These results are also recorded in table 13. From this table it may be seen that in the strength measurements highly significant interactions are found in six instances, significant interactions in one instance, and nonsignificant interations in four instances. Treatment does not affect elongation significantly in three cases, while significant differences are found in three instances, and highly significant differences in three others.

A detailed study of the means indicates the reason for significant differences in the results. For example, the mean of the warp abrasion-strength measurements for fabric 100 is greater at 15 dry cleanings, the same at 30 as at 15 dry cleanings, and lower at 45 than at 30 dry cleanings; for fabric 75 it is lower at 15, lower still at 30, and at 45 approximately the same as at 15; for fabric 50 it is the same at 15 as before dry cleaning, slightly lower at 30, and lower still at 45; and for fabric 25 it is slightly lower after each series of dry cleanings. Similar fabric behavior is found in the elongation measurements, where significant or highly significant results are recorded. While each individual fabric does not vary a great deal in its reaction to treatment, the dissimilar reaction of the other fabrics results in the significant differences found between treatments.

Thus, analysis of the data with the residual used as error leads to the conclusions that the four fabrics were significantly different in measurements of strength and elongation; the treatments to which the fabrics were subjected were significantly different; and in some instances the four fabrics did not react similarly to treatment as registered in terms of strength and elongation. Tables of the actual results show that the fabrics decreased in strength in progressing from the 100 percent new-wool fabric to the 25 percent new-wool fabric when similar manufacturing processes were employed. Elongation likewise decreased as the percentage of reprocessed fiber was increased. Dry cleaning and pressing increased strength in some instances and lowered it in others.

As is suggested above, it is desirable to expand the interpretation of the data to include an analysis of the effects of dry cleaning and pressing on flannel fabrics containing different percentages of new and reprocessed wool. For this purpose the interaction of blend $\times$ treatment is used as error. The results of these calculations are also reported in table 13. In making these interpretations, however, it is recognized that the inclusion of a larger number of blends and treatments would have been desirable and that the results are applicable only to blends in which the fiber properties are those found in this study. Thus all blends of new and reprocessed wool fiber would not necessarily produce fabrics having the properties found in this study.

Upon examination of the F values it may be seen that, regardless of treatment, varying the blend of new and reprocessed fibers appreciably in flannel fabrics yielded fabrics that differed significantly in strength and elongation. One exception to this finding was the elongation measurements during the determination of bursting strength, where it was found that all blends behaved similarly.

A second determination of importance involved testing for the significance of fabric treatment. In the strength measurements it is found that, regardless of blend, treatment effect is highly significant in four cases, significant in four, and nonsignificant in three. With the exception of tearing strength, in which both warp and filling directions are highly significant, the filling direction of the fabrics shows a greater tendency than the warp to give highly significant results. In several instances fabrics that are significantly different in one fabric direction are nonsignificant in the other. Thus the results of the application of the test of significance for the effects of fabric treatment on the strength of the fabrics are mixed.

In the effect of treatment on fabric elongation it is found that, regardless of blend, treatment affects elongation highly significantly in two instances, significantly in two, and nonsignificantly in five.

In summarizing the findings based on the second method of interpretation, it is shown that blending new and reprocessed wool fiber of the types employed in the present study in varying proportions and subjecting them to the same manufacturing processes resulted in fabrics of different strength and elongation, regardless of subsequent dry-cleaning and pressing processes. Dry cleaning and pressing the fabrics affected strength and elongation significantly in some instances and nonsignificantly in others, regardless of the blend.

SUMMARY

Wool flannel fabrics containing different blends of new and reprocessed fiber were manufactured, using identical spinning, weaving, and finishing processes. Chemical and physical tests were applied to the fabrics as received from the manufacturer and after varying numbers of commercial dry-cleanings and pressings.

Comparisons of the fiber qualities of the new and the reprocessed wool indicated that the new wool was finer, longer, and crimpier. No difference in average contour ratio was found.

Ash and nitrogen, were greater in the new fiber whereas the sulfur content was lower.

Examination of the fundamental properties of the four fabrics manufactured indicated that, when fibers of the nature described were used for blending, an increase in the percentage of reprocessed wool resulted in an appreciable decrease in the weight per square yard, though the number of yarns per inch decreased only slightly and the twist remained approximately the same.

Comparisons between the diameter of the fibers in the finished fabrics and those in the new and reprocessed wool from which the fabrics were made indicated that the coarser reprocessed fiber must have been eliminated to a certain extent during manufacture.

Determinations of the moisture, ash, nitrogen, and sulfur content of the fabrics before and after dry cleaning and pressing showed that the ash tended to increase with dry cleaning; that neither blend nor treatment affected the sulfur content appreciably; and that in all blends there was a marked increase in nitrogen between the fifteenth and thirtieth dry cleanings.

Statistical methods were applied in the analyses of the effects of abrasion and dry cleaning and pressing on the four fabrics. Nonsignificant differences in strength between unabraded fabrics and fabrics abraded 1,000 times were found. However, there was a decrease in elongation following abrasion.

When the interpretation of the results of the application of the analysis of variance was limited to comparisons between the four fabrics studied, it was found that the fabrics were significantly different in strength and elongation; the treatments to which they were subjected were significantly different; and in some instances they did not react similarly to treatment. Expanding the interpretation to indicate the general effects of blending new and reprocessed wool of the types used in this study in manufacturing flannel fabrics resulted in the conclusion that fabrics of different strength and elongation are produced, regardless of subsequent dry cleaning and pressing processes to which they may be exposed. Thus, regardless of the method of interpretation, it was found that increases in the percentage of the reprocessed wool used in this study resulted in corresponding decreases in fabric strength and elongation. The effects of dry cleaning and pressing were mixed and therefore inconclusive.

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